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This report summarizes accomplishments during the 3rd Quarterly reporting period. Our aim has been to improve the accuracy of the model described in the previous report andto predict v-E behavior in various alloys. The two valley-single electron temperature model was further generalized to calculate v-E characteristics without assuming a constant energt relaxation time. As the electric field is increased, the average energy of electrons increases. Electrons lose some energy to the lattice. The rate of energy loss is calculated by assuming that energy transfer takes place only through longitudinal optical phonons.

Based on our preliminary claculations, we conclude that alloys with constituent materials that exhibit an indirect gap are not suited for high speed devices. However, there are some interesting features to their behavior, e.g. a large negative temperature coefficient of the mobility which could prove to be useful in temperature sensors.

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SEMICONDUCTOR ENGINEERING FOR HIGH-SPEED DEVICES

Quarterly R&D Status Report No. 3

Covering the Period 16 December 1985 to 14 March 1986

16 March 1986

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I. Description of Progress

This report summarizes major accomplishments during the period 16 December to 14 March.

Our aim in this period has been to improve the accuracy of the model described in the previous report and to predict v-E behavior in various alloys.

The two valley-single electron temperature model was further generalized to calculate v-E characteristics without assuming a constant energy relaxation time. As the electric field is increased, the average energy of electrons increases. Electrons lose some energy to the lattice. The rate of energy loss is calculated by assuming that energy transfer takes place only through longitudinal optical phonons. Velocity-field graphs are obtained for a selection of direct gap alloys such as InP_xAs_{1-x}, $Ga_xIn_{1-x}Sb$, $Ga_xI_{1-x}As$, GaP_xAs_{1-x}, InP_xSb_{1-x}, $InAs_xSb_{1-x}$. The enclosed graph shows $\tilde{v}_p$, $\tilde{\mathcal{E}}_T^{-1}$, ΔE, and E_p as functions of x in these alloys, where $\tilde{V}_p$ and $\tilde{\mathcal{E}}_T^{-1}$ are peak velocity, and the reciprocal of the field $\tilde{\mathcal{E}}_T$ at the peak, both referenced to the values for GaAs where E_p is the minimum energy needed for an electron to produce an electron-hole pair, and ΔE is the energy separation between the conduction band edge and the minimum of the satellite valley. In the alloys where ΔE is larger than E_p avalanche breakdown is expected to occur before the peak velocity is reached. The alloys with $\tilde{v}_p > 1$, $\tilde{E}_T > 1$and $\Delta E > E_p$ are expected to be better candidates than GaAs for high speed devices. It is interesting to note that $\tilde{v}_p$ is greater in InPAs and InPSb alloys than that in the individual material. More detailed calculations on phonon properties are needed to confirm this prediction. If the additional criterion that E_g be greater than 0.8 eV, needed for devices to function at room temperature, is imposed, the only alloy that looks promising is InPSb. Similar curves will be generated for all the III-V compound alloys when our CRAY computer time becomes available. There are experimental data points included on the $\tilde{v}_p$ and $\tilde{\mathcal{E}}_T$ curves, and the agreement with this simplified theory is surprisingly good.

The simple model was also used to study the $Ga_xIn_{1-x}P$ system. This system exhibits a direct-to-indirect gap transition as x is increased. The effect of this transition on V-E is less interesting for high speed devices because indirect gap materials have lower mobilities and hence the peak velocity, v_p is small and the threshold field, $\mathcal{E}_T$ is large. Also because of large effective masses alloy scattering in these alloys limit the low field mobility substantially. Based on our preliminary calculations, we conclude that alloys with constituent material(s) that exhibit an indirect gap are not suited for high speed devices. However, there are some interesting features to their behavior, e.g., a large negative temperature coefficient of the mobility which could prove to be useful in temperature sensors.

In the next period, providing our CRAY time becomes available, band structure and velocity field characteristics will be calculated for all the promising alloys. Then group velocities of selected materials in interesting directions will also be calculated to help those designing ballistic transport systems. We also plan to begin to incorporate phonons into the CPA calculations on an equal footing with alloy scattering.

II. Equipment Purchased or Constructed

None

III. Trips, Meetings, Papers, and Visits

Dr. Arden Sher made a presentation on current activities at the 1986 DARPA Contractor Review, Naval Ocean Systems Center, San Diego, California, February 21-22.

IV. Problems or Areas of Concern

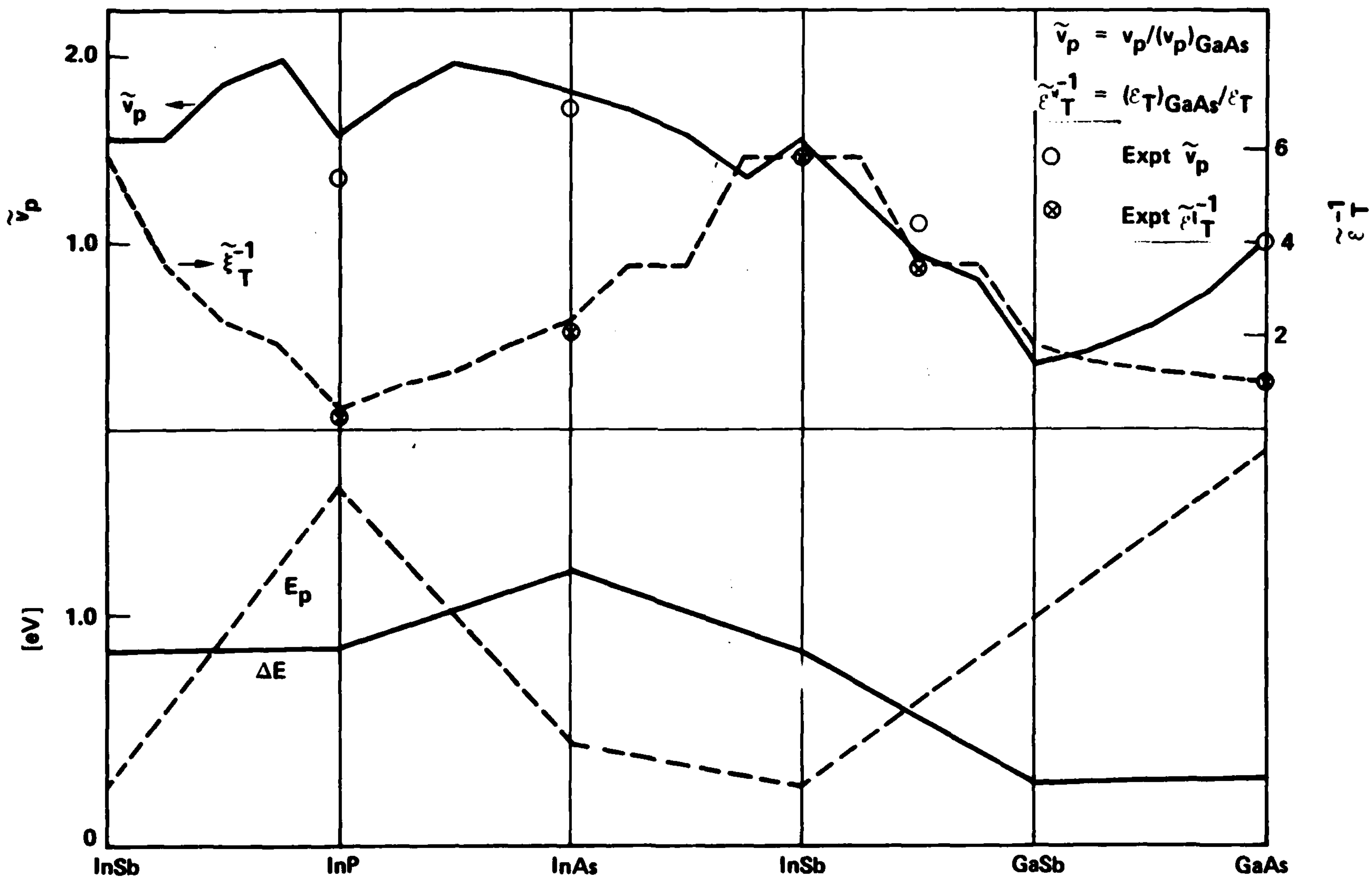
We have requested extra computer time and are waiting for official notification that time on a CRAY has been approved.

V. Deviation from Planned Effort

None

VI. Fiscal Status

The total contract funding for the three-year period is $611,296. Of this $195,287 is allocated to the first year. Including the burden, approximately $22,000 is intended to pay the consulting fee of An-Ban Chen leaving approximately $173,000. In the first three quarters ending 8 March 1985, we spent approximately $131,500, leaving $41,500 for the remaining quarter, ending 31 May 1986.



$\tilde{v}_p = v_p/(v_p)_{GaAs}$
$\tilde{\varepsilon}_T^{-1} = (\varepsilon_T)_{GaAs}/\varepsilon_T$
Expt $\tilde{v}_p$
Expt $\tilde{\varepsilon}_T^{-1}$
$\tilde{v}_p$
$\tilde{\varepsilon}_T^{-1}$
E_p
ΔE
[eV]
2.0
1.0
1.0
0
6
4
2
InSb
InP
InAs
InSb
GaSb
GaAs